Effect of live yeast supplementation to gestating sows and nursery piglets on postweaning growth performance and nutrient digestibility

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ABSTRACT: The objectives of the present study were to determine the effects of live yeast (**LY**) supplementation of sows during gestation and lactation and to determine the effects of supplementation of their offspring after weaning on growth performance and nutrient digestibility. A total of 40 sows were assigned to 2 dietary treatments (control vs. LY) based on parity and expected farrowing date. Birth weight, weaning weight, litter size, and mortality were measured. After weaning, 128 mixed-sex piglets (64 from each sow treatment) were selected based on their source litter and initial BW, and randomly assigned to 2 treatments (control or LY) at 4 pigs per pen (total of 32 pigs per treatment) for a 6-wk growth performance study. At the end of the growth performance trial, 2 barrows from each pen were moved to metabolism crates for total fecal collection for a digestibility trial. Addition of LY to the sow diets had no effects on birth weight, weaning weight, litter size at birth, and mortality. Piglets had greater BW on days 21 and 42 post-weaning when sows were fed diets supplemented with LY, and overall ADG was greater in piglets from sows that received LY ($P < 0.05$). There was no effect of sow and nursery diets on overall ADFI and G:F intake. Supplementing diets with LY during the nursery phase increased apparent total tract digestibility (**ATTD**) of DM, GE, and phosphorus (**P**) during this phase. The ATTD of GE was also greater in piglets from sows that received LY. In conclusion, LY supplementation of diets during gestation and lactation and during the nursery phase could increase ADG and ATTD of DM, GE, and P in the offspring, and this may lead to a greater lifetime growth performance in the offspring.

Key words: digestibility, growth performance, live yeast, piglets, sow

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INTRODUCTION

Modern sows have been selected for large litter size, increased milk production, and low body fat deposition (Meat and Livestock Commission, 2006; Jang et al., 2013). Therefore, sow nutrition management is critical not only for the health of sows, but also for the health and performance of piglets. Inadequate nutrition during gestation is associated with low birth weight and subsequent poor development of offspring (Barker, 1998). Achieving optimal sow nutrition during gestation and lactation is very important to the swine industry.

Several approaches have been used for improving the health of gestating and lactating sows. Live yeast (**LY**) supplementation in gestation and lactation diets has been shown to improve sow health status and growth performance of piglets before weaning (Kim et al., 2008; Shen et al., 2011; Jang et al., 2013). It has been reported that LY supplementation could increase milk production in cows (McCoy et al., 1997; Desnoyers et al., 2009), and LY has been shown to enhance growth performance, nutrient digestion, and immune status of nursery pigs (Kornegay et al., 1995; Van Heugten

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et al., 2003; Van der Peet-Schwering et al., 2007; Shen et al., 2009). However, little is known about effects of LY supplementation during gestation and lactation on growth performance of weanling pigs. Therefore, the objectives of this study were to determine the effects of LY (*Saccharomyces cerevisiae* spp.) supplementation in sow diets during gestation and lactation on growth performance and nutrient digestibility of their offspring, and to determine effects of LY supplementation during the nursery period on growth performance and nutrient digestibility.[AU: Please note that BW, DM, G:F, ADG, ADFI, CP, GE, DE, NDF, ADF are standard abbreviations that can be used without definition. This article has been amended accordingly. Please check and confirm.]

MATERIALS AND METHODS

Animals and Sample Collection

All animal procedures were approved by the Purdue University Animal Care and Use Committee. All the pigs used in this study were obtained from Purdue University Swine Research Unit. A total of 40 sows were used in this study. Sows (Yorkshire-Landrace) were assigned to 2 dietary treatments (20 per treatment), control and LY, based on their parity (1 to 7) and expected farrowing date. Sows received 3.5 kg of feed daily in 2 equal installments (07:00 and 15:00) as practiced at the Purdue University Swine Research Unit. About 1 wk prior to farrowing, sows were moved to farrowing crates. Two sows from the control and 3 from the LY treatments were later confirmed to not be pregnant and removed from the study. Newly born piglets were weighed about 48 h after farrowing. Litter size at birth per sow and mortality were recorded. Piglets were weaned at an average of 21 d of age.

A total of 128 weaning piglets were selected for the nursery growth performance trial. Each half of the piglets came from sows that received either the control or the LY supplemented diets during gestation and lactation. Piglets from each sow group were randomly assigned to 2 dietary treatments (control and LY) based on their litter, age, and weaning weight at 4 pigs per pen and 8 replicate pens per treatment. There were 4 pens of gilts and 4 pens of barrows. Pigs from the same litter were assigned to different pens for proper randomization. Pigs were fed experimental diets for 6 wk in 2 feeding phases (days 0 to 21 and 21 to 42). On days 21 and 42, pigs were weighed individually. Feed disappearance and G:F were measured for phases 1 and 2. At the end of the growth trial, 32 barrows (2 per pen) were selected for a digestibility trial using marked feed as described by Adeola (2001). Pigs were moved to stainless steel metabolism crates. Pigs were adapted to the crates for 4 d followed by a 3-d collection of feces. Pigs were fed their daily ration at 4% of average initial BW within each replicate. Pigs were fed their daily ration in 2 equal installments at 0700 and 1700 h. Ferric oxide and chromic oxide (5 g/100 g of feed) were used as markers to determine the initiation and termination of fecal collection. All the feces were stored at −20 °C and pooled within each pig until further analysis. The following parameters were measured for digestibility: DM, GE, nitrogen (**N**), phosphorus (**P**), calcium (**Ca**).

Dietary Treatments

Two dietary treatments were used in the gestation and lactation periods for the sows. A control diet and a LY (*S. cerevisiae*, 2×10^{10} CFU/g, Vistacell, AB Vista, UK) supplemented diet at 0.5 g/kg during gestation and 1 g/kg during lactation. The composition of the control diet for the gestation and lactation diets are presented in Table 1. For growth performance and digestibility trials, a control diet that met the nutrient requirements of pigs for each growth phase (NRC, 2012) was used, and LY was supplemented in piglet diet at 1 g/kg. The control diet compositions for each phase were presented in Table 2.

Chemical Analyses

Fecal samples were pooled and oven-dried at 55 °C to a constant weight. Diets and fecal samples were ground and dried at 105 °C in a drying oven (Precision Scientific Co., Chicago, IL) for 24 h to determine the DM content (method 934.01; AOAC, 2006). Gross energy was determined on a bomb calorimeter (Parr 1261 bomb calorimeter, Parr Instruments Co., Moline, IL). To determine P and Ca concentration, diets and fecal samples were ashed in a muffle furnace at 600 °C for 16 h; the ashed samples were digested in 20 mL of 4 M HCl and 5 drops of concentrated nitric acid for about 7 min on a hot plate; and the digested samples were moved into 250-mL volumetric flasks. Phosphorus concentrations were measured by spectrophotometric reading of absorbance at 620 nm using the method described by Zhai and Adeola (2013). Concentration of Ca in the supernatant was determined using flame atomic absorption spectrometry (Varian FS240 AA Varian Inc., Palo Alto, CA). Nitrogen content was determined with the combustion method on a model FP-2000 nitrogen analyzer (Leco Corp., St. Joseph, MI).

Table 1. Ingredient composition of control sow gestation and lactation diets, as-fed basis[1]

Ingredient, g/kg	Gestation	Lactation
Corn	707.4	589.3
Soybean meal	141.0	280.0
Corn DDGS[9]	100.0	50.0
Plasma	0.0	5.0
Swine grease	10.0	30.0
Limestone	14.4	13.9
Monocalcium phosphate	10.7	15.3
Vitamin premix[2]	2.5	2.5
Sow vitamin premix[3]	2.5	2.5
Mineral premix[4]	1.3	1.3
Selenium premix[5]	0.5	0.5
Phytase premix[6]	1.0	1.0
Salt	5.0	5.0
Availa Zn 120[7]	0.4	0.4
Clarifly[8]	3.3	3.3
Total	1,000	1,000
Calculated composition		
ME, kcal/kg	3,270	3,287
CP, g/kg	152	153
Ca, g/kg	8.0	8.0
Total P, g/kg	5.7	5.7
STTD[10] P, g/kg	3.4	3.4

[1]Live yeast was added to the control diets as a replacement for corn in a premix to supply 0.5 and 1 g/kg for gestation and lactation, respectively.

[2]Vitamin premix supplied per kilogram of diet: 3,635 IU vitamin A, 363 IU vitamin D3, 26.4 IU vitamin E, 3.6 mg vitamin K, 1,206 µg menadione, 21.2 µg vitamin B12, 4.2 mg riboflavin, 13.5 mg d-pantothenic acid, and 19.5 mg niacin.

[3]Sow Vitamin Premix, Provimi, Lewisburg, OH.

[4]Mineral premix supplied per kilogram diet: 9 mg Cu (as copper sulfate), 0.29 mg I (as Ca iodate), 105 mg Fe (as ferrous sulfate), 13 mg Mn (as manganese oxide) and 105 mg Zn (as zinc oxide).

[5]Supplied 300 µg of Se per kg of diet.

[6]Phytase (Quantum Blue, AB Vista, Marlborough, UK) premix was added at 1 g/kg to supply 500 FTU/kg phytase.

[7]Availa Zn 120, Zinpro, Eden Prairie, MN.

[8]ClariFly Larvicide 0.67%, Central Life Sciences, Schaumberg, IL.

[9]Dried distillers grains with solubles.

[10]Standardized total tract digestibility.

Table 2. Ingredient composition of control nursery diets in phases 1 and 2, as-fed basis[1]

Ingredient, g/kg	Phase 1	Phase 2
Corn	368.7	514.6
Soybean meal	150.0	257.5
Corn DDGS[7]	0.0	150.0
Oat groats	125.0	0.0
Soycomil-P[2]	82.5	0.0
Fish meal	35.0	0.0
Whey	200.0	25.0
Soybean oil	8.0	24.0
Monocalcium phosphate	3.5	0.0
Limestone	9.6	11.3
Salt	2.5	4.5
L-Lysine	3.4	4.5
DL-Methionine	1.7	0.9
L-Threonine	0.9	0.9
L-Tryptophan	0.0	0.0
ZnO	3.5	1.5
$CuSO_4$	1.0	0.5
Vitamin premix[3]	2.5	2.5
Mineral premix[4]	1.5	1.5
Selenium premix[5]	0.5	0.5
Ethoxiquin (Quinguard)[6]	0.3	0.3
Total	1,000	1,000
Analyzed nutrients and energy (as-fed basis)		
GE, kcal/kg	4,345.2	4,116.0
CP, g/kg	220	256
Calcium, g/kg	8.0	7.1
Phosphorus, g/kg	6.4	5.0
ADF, g/kg	35.2	27.9
NDF, g/kg	108.5	101.5

[1]Live yeast was added to control diets as a replacement for corn in a premix to supply 1 g/kg.

[2]Soycomil-P, ADM, Decatur, IL.

[3]Vitamin premix supplied per kilogram of diet: 3,635 IU vitamin A, 363 IU vitamin D3, 26.4 IU vitamin E, 3.6 mg vitamin K, 1,206 µg menadione, 21.2 µg vitamin B12, 4.2 mg riboflavin, 13.5 mg d-pantothenic acid, and 19.5 mg niacin.

[4]Mineral premix supplied per kilogram diet: 11.3 mg Cu (as copper sulfate), 0.34 mg I (as Ca iodate), 121 mg Fe (as ferrous sulfate), 15 mg Mn (as manganese oxide), and 121 mg Zn (as zinc oxide).

[5]Supplied 300 µg of Se per kg of diet.

[6]Quinguard, Novus, St. Charles, MO.

[7]Dried distillers grains with solubles.

Calculations and Statistical Analysis

The apparent total tract digestibility (**ATTD**, %) of GE and nutrient were calculated using the following equations described by Adeola (2001):

$$\text{ATTD} = 100 \times (N_i N_f)/N_i,$$

where N_i is the dietary GE and nutrients intake (g/d) and N_f is the fecal GE and nutrients output (g/d).

For litter birth weight, weaning weight, litter size, and preweaning mortality, litter was the experimental unit, and data were analyzed using a paired *t*-test. For growth performance and digestibility data, pen or individual pig was the experimental unit. Data were analyzed using MIXED procedures of SAS (SAS Inst. Inc., Cary, NC) for a split-plot arrangement with sow diet as the whole plot and nursery diet as split plot. An α level of 0.05 was considered significant. Means were separated using PDIFF option of SAS (2006).

RESULTS

Litter size at birth, litter weight at birth, and preweaning mortality were not different between control and LY (Table 3). Weaning weight (5.64

vs. 5.84 kg) and litter weaning weight (51.3 vs. 59.6 kg), although numerically higher for LY supplemented sows, were not different from control. Body weight was greater at days 21 and 42 post-weaning with LY supplementation during gestation and lactation compared with the control (Table 4; $P < 0.05$). Supplementation with LY in the nursery diet tended ($P = 0.07$) to increase BW.

For phase 1 (days 0 to 21 after weaning), ADG was greater in piglets from sows supplemented with LY compared with those from control sows. However, sow treatment had no effect on ADFI and G:F (Table 4). Supplementation with LY during nursery phase 1 increased ADFI ($P = 0.03$) during this phase. For phase 2, piglets from sows that received LY and that had also received LY in the nursery feed had a higher G:F compared with other groups ($P < 0.01$). Overall, ADG was greater ($P < 0.05$) in piglets from sows that were supplemented with LY compared with those from control sows. Furthermore, LY supplementation in the nursery phase increased ATTD of DM, GE, and P ($P < 0.01$; Table 5), and ATTD of GE was higher in piglets from sows fed LY during gestation and lactation ($P = 0.01$).

DISCUSSION

Gestation, lactation, and the first 2 wk post-weaning are critical periods in the development and growth of pigs (Wu et al., 2014). The effect of exposure to any negative environment during gestation and lactation in sows is often reflected in impaired growth performance of their offspring (Ji et al., 2016).

Live yeast is considered a probiotic that can colonize the gastrointestinal tract (**GIT**) of animals. This colonization can inhibit the growth of pathogenic bacteria (Shurson, 2018). Although it has been previously reported that LY supplementation of gestation diets could lead to increases in the number of piglets born alive and reduction in preweaning mortality (Mariella et al., 2009), LY had no effects on litter size, preweaning mortality,

Table 3. Effect of live yeast supplementation in sow diets on preweaning growth of piglets[1]

	Control	LY	SD	*P*-value
Birth wt, kg	1.69	1.72	0.32	0.82
Weaning wt, kg	5.64	5.84	1.1	0.73
ADG, g	202	203	7.7	0.94
Litter size at birth	11.5	12.7	3	0.19
Litter weaning weight, kg	51.3	59.6	12.9	0.13
Preweaning mortality, %	1.89	2.18	2.2	0.73

[1]$n = 18$ and 17 sows for control and LY treatments, respectively. LY = live yeast.

Table 4. Effect of live yeast supplementation on growth performance of piglets after weaning[1]

Sow diet	Control		LY				*P*-value	
Nursery diet	Control	LY	Control	LY	SEM[2]	SEM[3]	Sow diet	Nursery diet
BW day 0, kg	6.4	6.4	6.4	6.4	0.26	0.28	0.52	0.87
BW day 21, kg	11.2	12.0	12.2	12.1	0.22	0.57	0.04	0.23
BW day 42, kg	21.7	22.4	22.6	23.0	0.30	0.82	0.02	0.07
Phase 1								
ADG, g	229	266	276	273	8.92	16.87	0.02	0.19
ADFI, g	356	391	385	410	10.86	23.20	0.09	0.03
G:F, g/kg	643	680	721	671	10.43	23.09	0.16	0.52
Phase 2								
ADG, g	501	493	497	521	7.12	15.74	0.30	0.14
ADFI, g	866	874	900	851	14.02	35.70	0.74	0.39
G:F, g/kg	580[b]	565[b]	554[b]	619[a]	7.97	16.10	0.27	0.02
Overall								
ADG, g	365	380	386	397	6.39	14.13	0.01	0.04
ADFI, g	611	632	642	631	11.20	27.31	0.25	0.47
G:F, g/kg	598	600	604	634	6.09	11.23	0.06	0.11

[a,b]Means within rows without a common superscript are different at $P < 0.05$.

[1]Data are means of 8 replicate pens with 4 pigs per pen. LY = live yeast.

[2]Standard error of the mean for the whole plot (sow diet).

[3]Standard error of the mean for the split plot (nursery diet).

Table 5. Effect of LY supplementation on apparent total tract nutrient digestibility in piglets[1]

Sow diet	Control		LY				*P*-value	
Nursery diet	Control	LY	Control	LY	SEM[2]	SEM[3]	Sow diet	Nursery diet
%								
DM	84.9	85.9	85.3	86.5	0.20	0.26	0.11	<0.001
GE	83.2	84.4	84.1	85.3	0.28	0.32	0.01	<0.001
N	84.6	85.1	85.1	86.0	0.18	0.46	0.13	0.12
P	41.4	47.3	44.2	49.9	0.54	1.46	0.08	<0.001
Ca	70.0	73.2	71.0	72.3	1.19	2.37	0.99	0.35

[1]Data are means of 8 pigs per treatment. LY = live yeast, N = nitrogen, P = phosphorus, Ca = calcium.

[2]Standard error of the mean for the whole plot (sow diet).

[3]Standard error of the mean for the split plot (nursery diet).

birth weight, weaning weight, and preweaning daily gain in this study. However, preweaning mortality was already very low in the control treatment (1.89%), and any further improvement by LY was not expected.

These results are consistent with the finding of Jang et al. (2013) who found that LY supplementation at 10^6 and 10^7 CFU/kg diet during gestation and lactation had no effect on litter size, number of live births, and litter weight at birth and weaning. In contrast, positive effects of yeast culture have been reported by Kim et al. (2008) on preweaning weight gain. However, unlike LY, yeast culture contains culture media, which may have additional nutrients that may increase preweaning gain. It has also been reported that LY could increase total milk solids and CP concentrations (Jurgens et al., 1997). However, other studies (Lindemann et al., 2010; Jang et al., 2013) reported that there was no effect of hydrolyzed yeast or LY on milk composition and milk production.

Supplementation of diets with LY during gestation and lactation increased postweaning BW 21 and 42 d after weaning by 4.4% and 3.5%, respectively. The ADG from weaning to 21 and 42 d post-weaning was increased by LY supplementation in the gestation and lactation diets, although there was no effect on postweaning feed intake. This is similar to the report by Jurgens et al. (1997) that supplementation with active dry yeast during gestation, lactation, and nursery phases increased ADG from weaning to 28 d compared with control without LY supplementation. However, this study was different from the work performed by Jurgens et al. (1997) because they could not separate the effect of yeast supplementation during the nursery phase from that due to the gestation/lactation phases as was performed in this study. To our knowledge, this research is the first to determine the carryover effect of LY from gestation and lactation on nursery-phase growth performance. It is possible that the effect of maternal LY supplementation on growth performance of offspring was mediated through promotion of growth of beneficial bacteria and resistance to local infection (Bontempo et al., 2006; Chaucheyras-Durand and Durand, 2010). Studies in humans found that microbes that are stimulated by probiotic supplementation during pregnancy could be transferred to the neonatal GIT (Sanz, 2011). A recent study (Hasan et al., 2018) reported that yeast supplementation to sows during gestation and lactation could increase the relative abundance of beneficial and fermentative bacteria (*Roseburia*, *Paraprevotella*, and *Eubacterium*) and suppress pathogens such as *Proteobacteria* in sows. With yeast supplementation, the fecal microbiome in piglets at 1-wk age was more diverse with more beneficial microbial population and less opportunistic pathogens. Thus, the positive effects of LY supplementation during gestation and lactation on growth performance of pigs after weaning in the present study could probably be due to the beneficial effects of maternal gut microbiota that was transferred to the offspring.

The BW at day 21 post-weaning was not affected by LY supplementation during nursery phase, but a higher BW and ADG with dietary LY supplementation was observed at day 42 post-weaning. Studies have reported that LY or yeast culture supplementation to weanling pigs increased growth performance (Mathew et al., 1998; Van Heugten et al., 2003; Van der Peet-Schwering et al., 2007; Shen et al., 2009). However, others reported a lack of effect of LY on growth (Jurgens, 1995; Kornegay et al., 1995). The exact mechanism of positive effects of LY on growth performance is still unclear. Possible reasons for this observation could be associated with potential effects of LY on feed intake, digestive enzyme secretion, and bacteria balance (Shen et al., 2009; Chaucheyras-Durand

and Durand, 2010). In support of this possibility, LY supplementation increased feed intake from weaning to 21 d post-weaning. A similar result of a positive effect of LY or yeast culture on feed intake was reported by Mathew et al. (1998) and Shen et al. (2009). However, other studies have also reported a lack of effect of LY on feed intake (Kornegay et al., 1995; Van der Peet-Schwering et al., 2007). Another possibility is the immaturity of the gut microbiome within the first 21 d post-weaning and the more mature GIT at 42 d post-weaning (Kim et al., 2012; Holman and Chénier, 2014). It has been reported that LY increased neutral detergent fiber digestion in dogs and cows by increasing the fibrolytic bacteria and fungi colonization in the GIT (Chaucheyras-Durand et al., 2016; Stercova et al., 2016). In a recent study in pigs, Kiros et al. (2018) found that oral gavage of LY during the preweaning period and LY supplementation during the postweaning period could improve pig health by promoting beneficial bacteria abundance. However, there was no effect on growth performance at day 28 post-weaning when LY was provided only during the postweaning period. Therefore, they suggested that yeast supplementation during the postweaning period might have happened too late to affect growth performance.

The observed increased ATTD of DM, GE, and P with LY supplementation during the nursery phase is consistent with the findings of Shen et al. (2009) and Liu et al. (2018). It has been reported that LY supplementation could increase cellulolytic microbiome counts in ruminants (Newbold et al., 1995) and increase the digestion of fiber in horses and piglets (Jouany et al., 2008; Lizardo et al., 2012). This potential greater breakdown of fiber by the microbiome may account for the higher GE noted in the study. It has been previously suggested that fermentation of dietary fiber may affect the intestinal availability of P in pigs (Metzler and Mosenthin, 2008). Similar result of increased P digestibility was reported in broilers fed with yeast culture (Gao et al., 2008). Kim et al. (2014) also reported that yeast supplementation resulted in greater standardized total tract digestibility of P compared with soybean meal in growing pigs. Further studies are needed to investigate the observed increase in ATTD of P with LY supplementation.

In conclusion, the present study indicates that LY supplementation during gestation and lactation increased the growth performance of piglets after weaning. LY supplementation during the nursery phase increased ATTD of DM, GE, and P as well as improved growth performance. The beneficial effects of LY supplementation during gestation, lactation, and nursery phases on growth performance and nutrient digestibility could probably be due to enhanced gut microbial diversity. However, further research is needed to confirm this assumption.

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